

Title:

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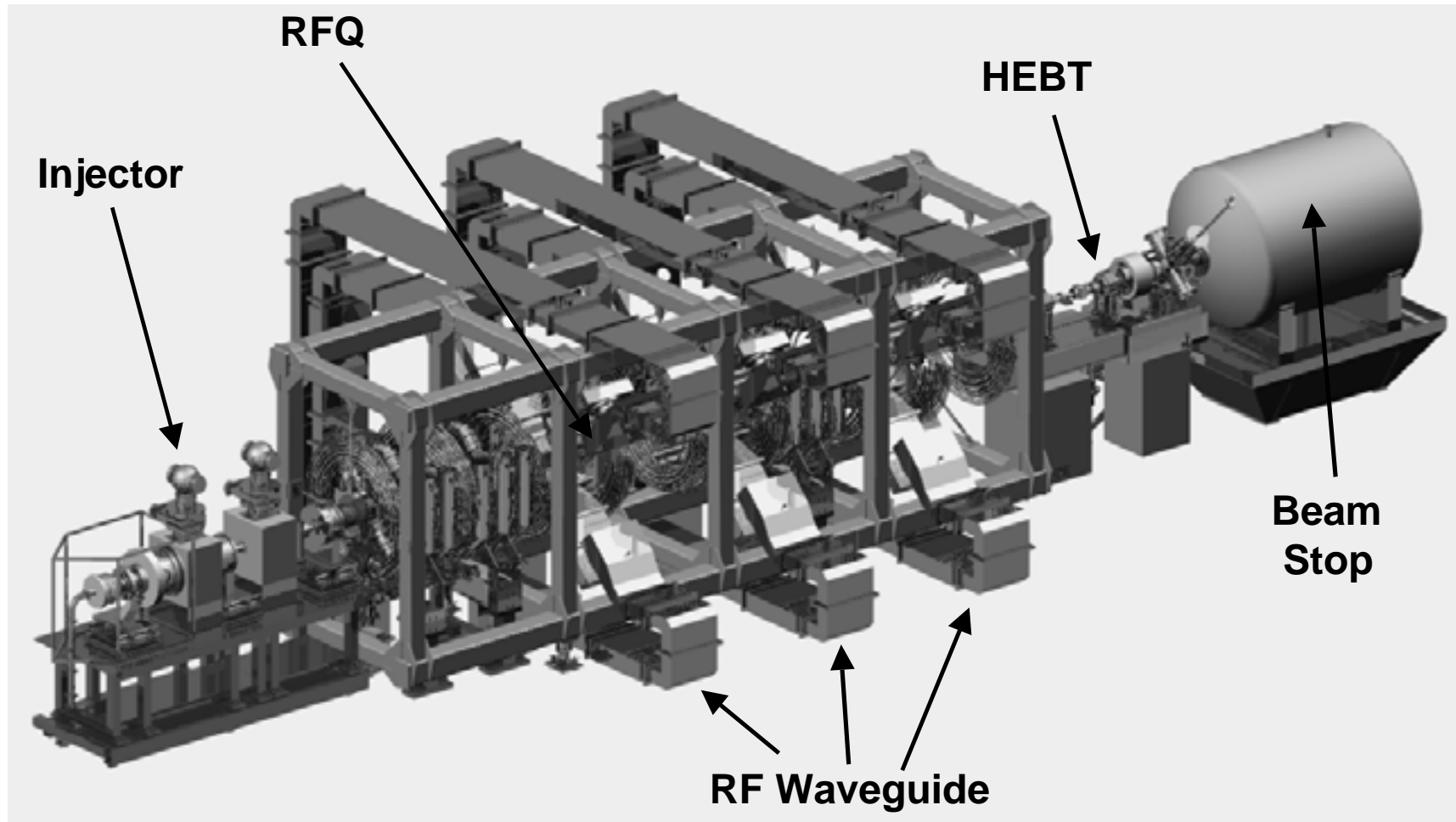
Abstract

- The LEDA RFQ is a 100% duty factor (CW) linac that delivers >100 mA of 6.7 MeV H⁺ beam with $\approx 94\%$ RFQ transmission
- It has been operated for >30 hr cumulative for RFQ output beam currents ≥ 100 mA CW and for >70 hr cumulative for ≥ 90 mA CW
- At ≥ 100 μ sec into ≥ 90 mA beam pulses the RFQ transmission abruptly drops below the PARMTEQM prediction
- Raising the rf field level to 105-110% of design restores the RFQ transmission to the 100% rf field prediction
- Preliminary analysis of the quadrupole-magnet-scan emittance measurements indicates the RFQ output beam rms emittance $\varepsilon_x \approx 0.25 \pi$ mm mrad (normalized), within the experimental error of the PARMTEQM-predicted value of 0.23π mm mrad

LEDA is a Test Bed to Demonstrate Components to be Used in the Front End of an APT Plant

- **Components already demonstrated include**
 - **75-keV, 110-mA proton injector**
 - **6.7-MeV, 100-mA RFQ**
 - **350-MHz rf system, including the LLRF**
 - **Simple HEBT transport and 670-kW beamstop**
 - **Beam diagnostics**
- **Components to be demonstrated in the future**
 - **11-m-long FODO channel to measure beam halo**
 - **7.28-MeV CCDTL**

LEDA Consists of an Injector, 6.7-MeV RFQ, HEBT, and Beamstop

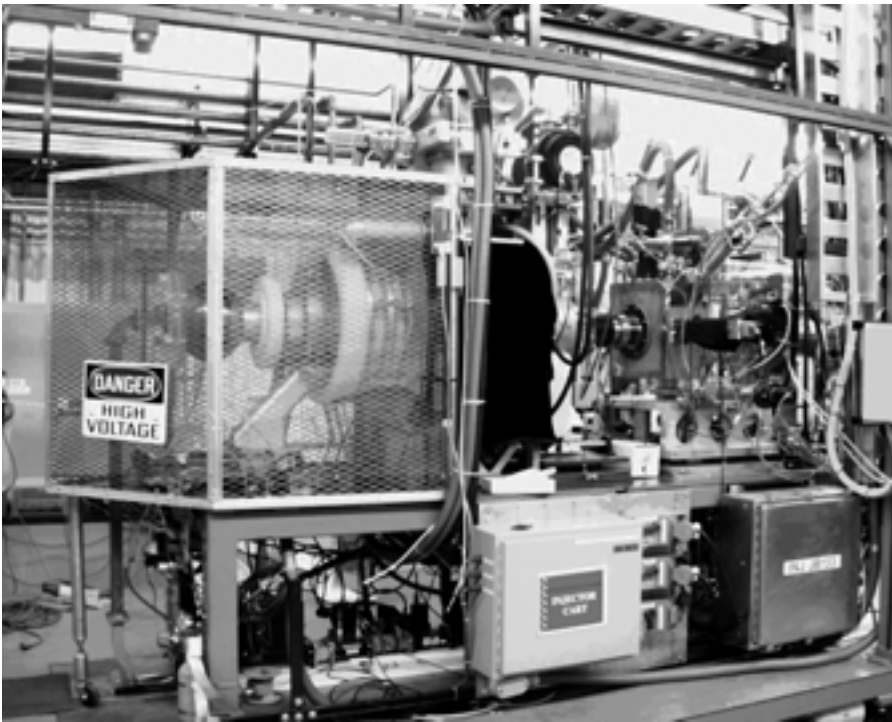


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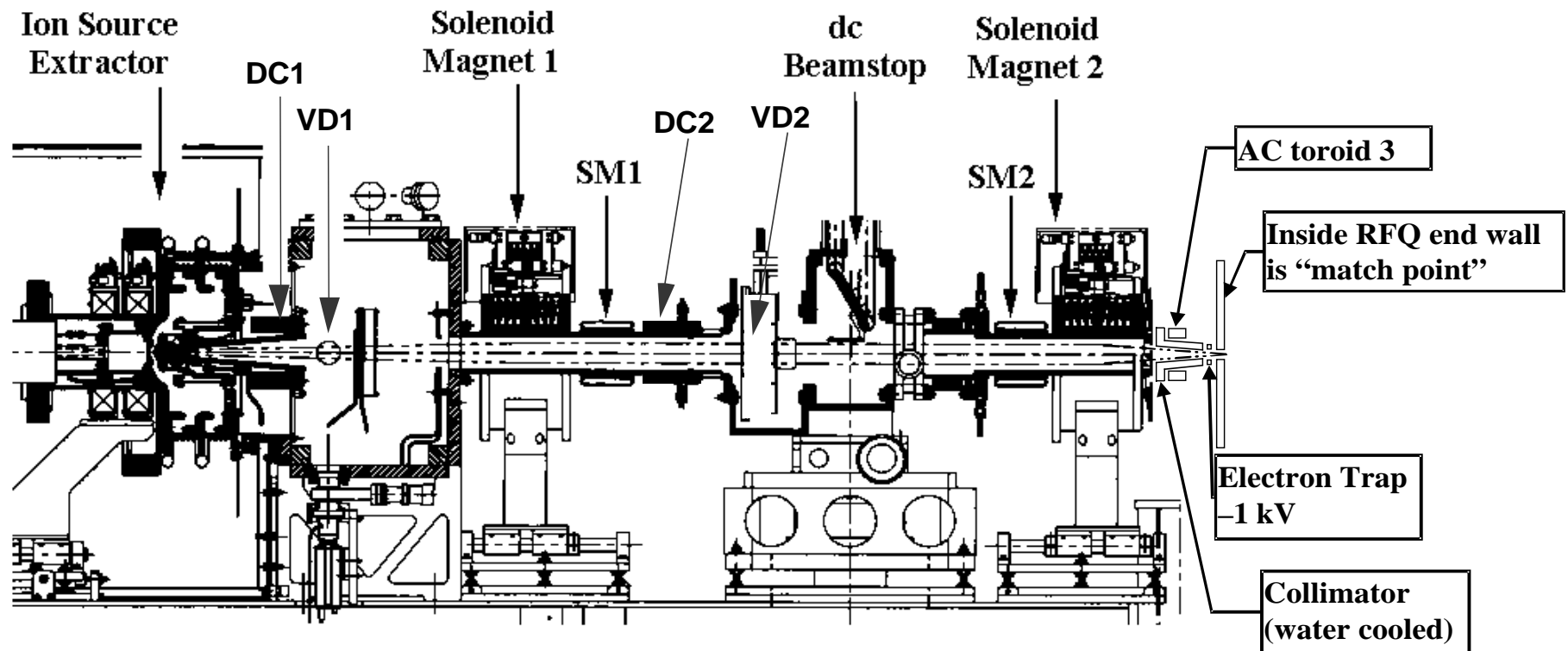
LEDA 
Accelerator
Production
of Tritium

The injector matches a dc 75-keV, 110-mA proton beam into the LEDA RFQ



- **Key injector components**
 - 2.45-GHz microwave ion source
 - single-gap extractor
 - dual magnetic solenoid, gas-neutralized LEBT
- **Key ion source parameters**
 - 800-1200 W of 2.45-GHz microwave power
 - $85\% \leq \text{proton fraction} \leq 95\%$
- **Key injector beam parameters**
 - proton current ≥ 110 mA at 75-keV
 - emittance $< 0.2 \pi$ mm-mrad (normalized)

The LEDA injector beam diagnostics are used to characterize the RFQ input beam.

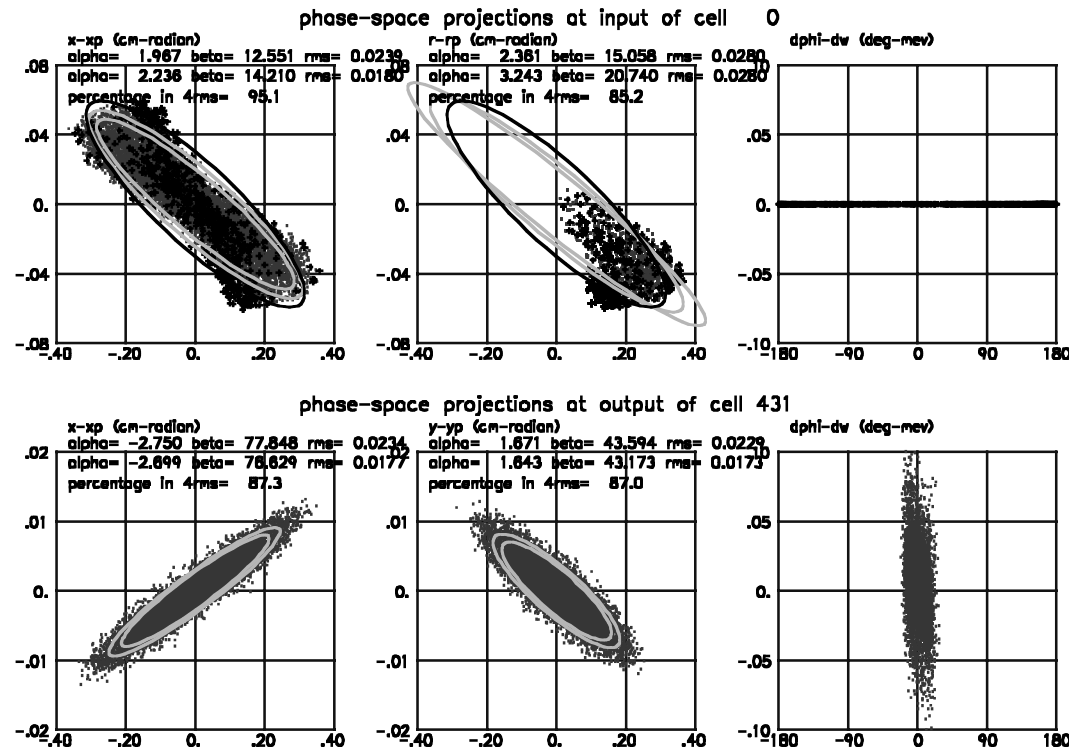


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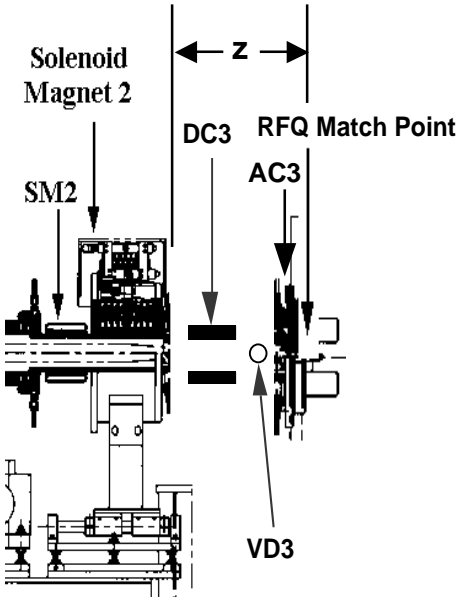
PARMTEQM calculates the RFQ output emittance is 0.232π mm mrad for the 100-mA H⁺ beam.

350.000MHz,q= 1.0,Ws=0.085,Wq=0.300,A=0.265,amu=1.00728,i=100.0mA shar dist



PARMTEQM-calculated RFQ input (top) and output (bottom) phase space for 100 mA input current). The 5000-particle input beam is derived from the SCHAR-calculated file for the 100-mA beam. PARMTEQM calculates the RFQ transmission is 92.2% for the 100-mA H⁺ beam.

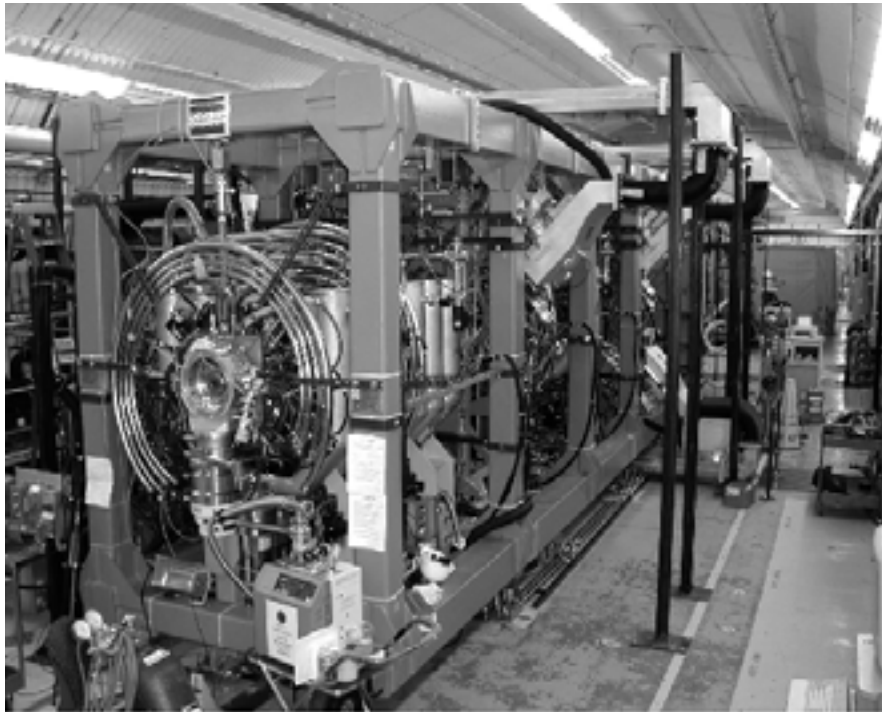
Changes made in the LEBT during RFQ commissioning.

- The shape of the iron core in the first solenoid was changed to lower the lens aberrations
- 
 - The distance z between the second solenoid lens and the RFQ entrance was shortened to increase the beam convergence angle into the RFQ
 - An electron trap was placed just in front of the RFQ to minimize the space-charge-induced beam expansion in front of the RFQ
- Lloyd Young discussed these changes in his 1999 Physics of High-Brightness Beams paper

We measured the RFQ performance using triode and tetrode extraction geometries.

- **PBGUNS predicts that, for the same emitter, extractor, and gap dimensions the triode will produce larger currents and lower divergence**
- **RFQ measurements confirm this prediction but**
 - **The injector spark-down rate is higher with the triode than with the tetrode**
 - **RFQ rf fault recovery is faster with the tetrode, with little or no operator intervention**
- **The tetrode extraction system was used for the measurements presented here**

The 350-MHz RFQ accelerates 100 mA of protons to 6.7 MeV.



LEDA RFQ with the injector rolled back.

- **Key RFQ components**
 - vanes, vacuum vessel, and support structure
 - resonance-control cooling system
 - RF power feeds
 - vacuum system
- **Key RFQ parameters**
 - structure power - 1.5 MW average
 - RF feeds - 6 waveguide irises
 - cavity vacuum pumping - 3600 T-//s
 - cooling water - ~1300 gpm at 50° F
- **6.7-MeV, 100-mA RFQ output beam**
 - power - 670 kW CW
 - rms trans. normalized emittance - 0.22π mm mrad
 - long. emittance - 0.174 deg-MeV

WAVE GUIDE
WR 2300
HALF HIGH
4 @LOCATION

313.69

SEGMENT -A-
38.73 SECTION A1
39.35 SECTION A2
VACUUM PORTS
4 @ LOCATION
12 per SECTION
SECTIONS A1&A2
98.01
COUPLING PLATE
.50 THICK

SEGMENT -B-
39.59 SECTION B1
39.64 SECTION B2
COUPLING PLATE
.50 THICK

SEGMENT -C-
38.74 SECTION C1
39.73 SECTION C2
VACUUM PORTS
4 @ LOCATION
12 in SECTION
COUPLING PLATE
.50 THICK

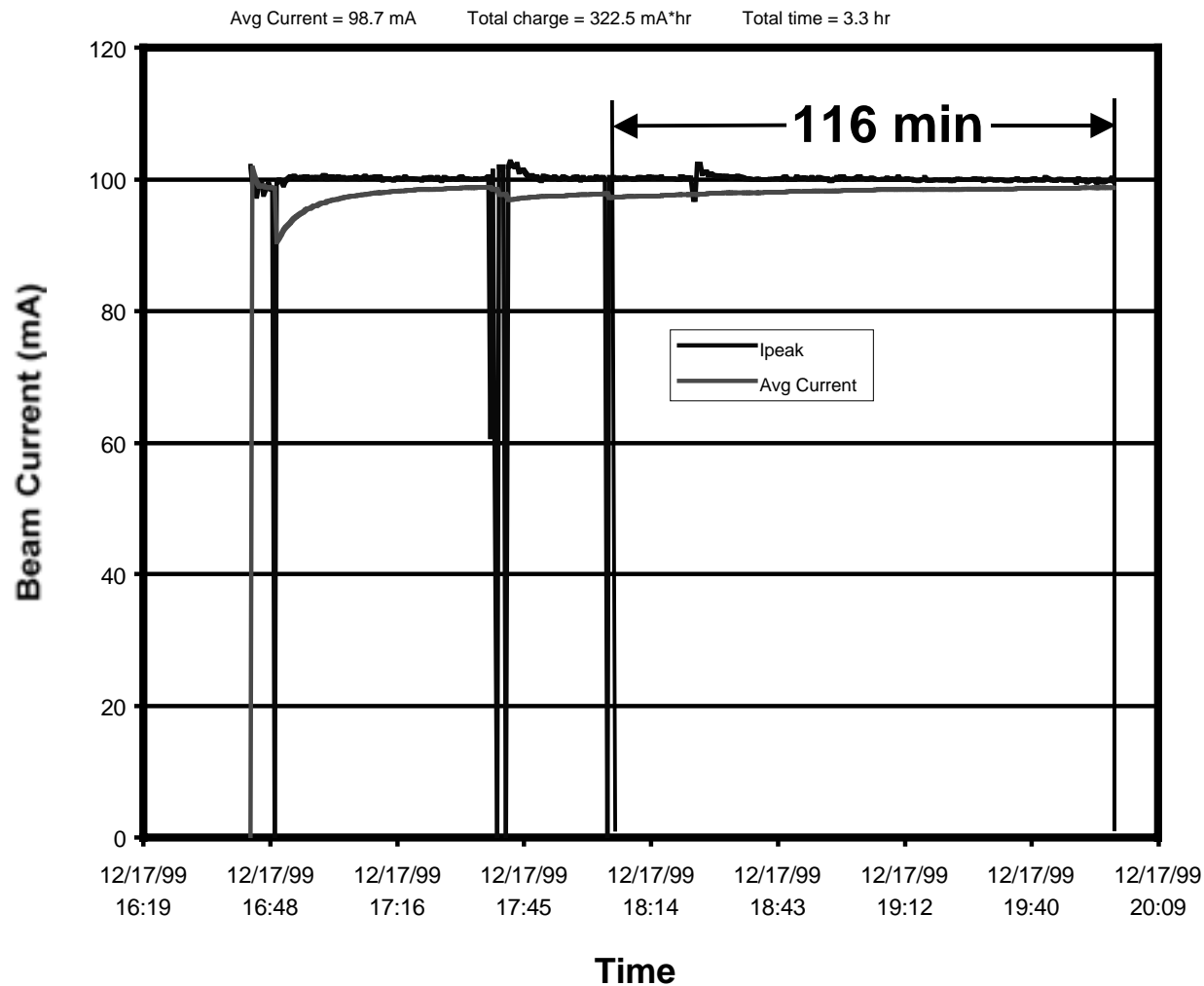
SEGMENT -D-
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23.00
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255.51

294.47

- LEDA**  Accelerator
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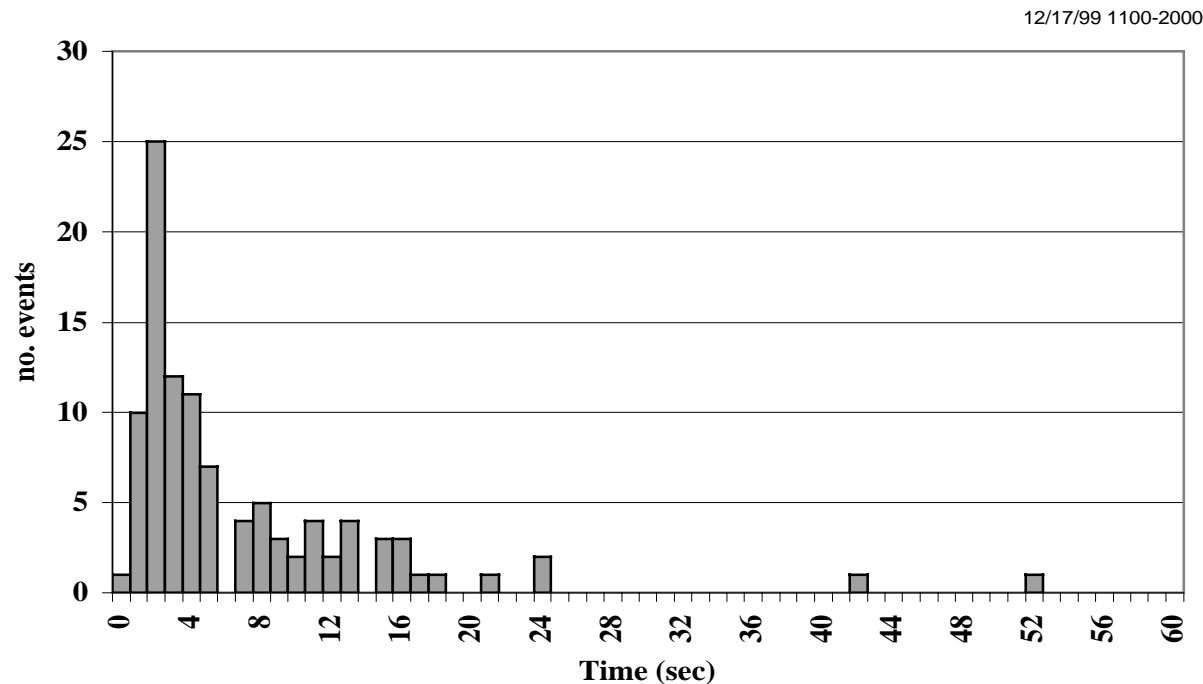
The LEDA RFQ has run a 100-mA, CW beam for 116 min uninterrupted.



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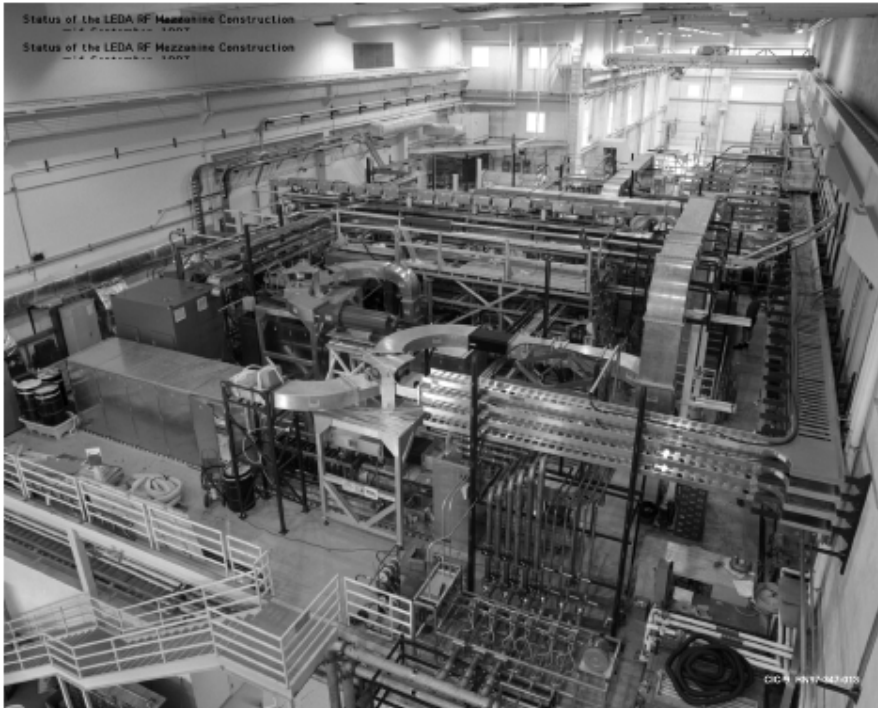
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During the 116 minute run most of the beam interruptions were 1-6 sec in duration.



- The bulk of these trips were injector sparks that recovered quickly and automatically. LLRF frequency lock was not lost.

The High-Power RF System Converts 13.2-kV ac Site Power to 350- and 700-MHz RF Power



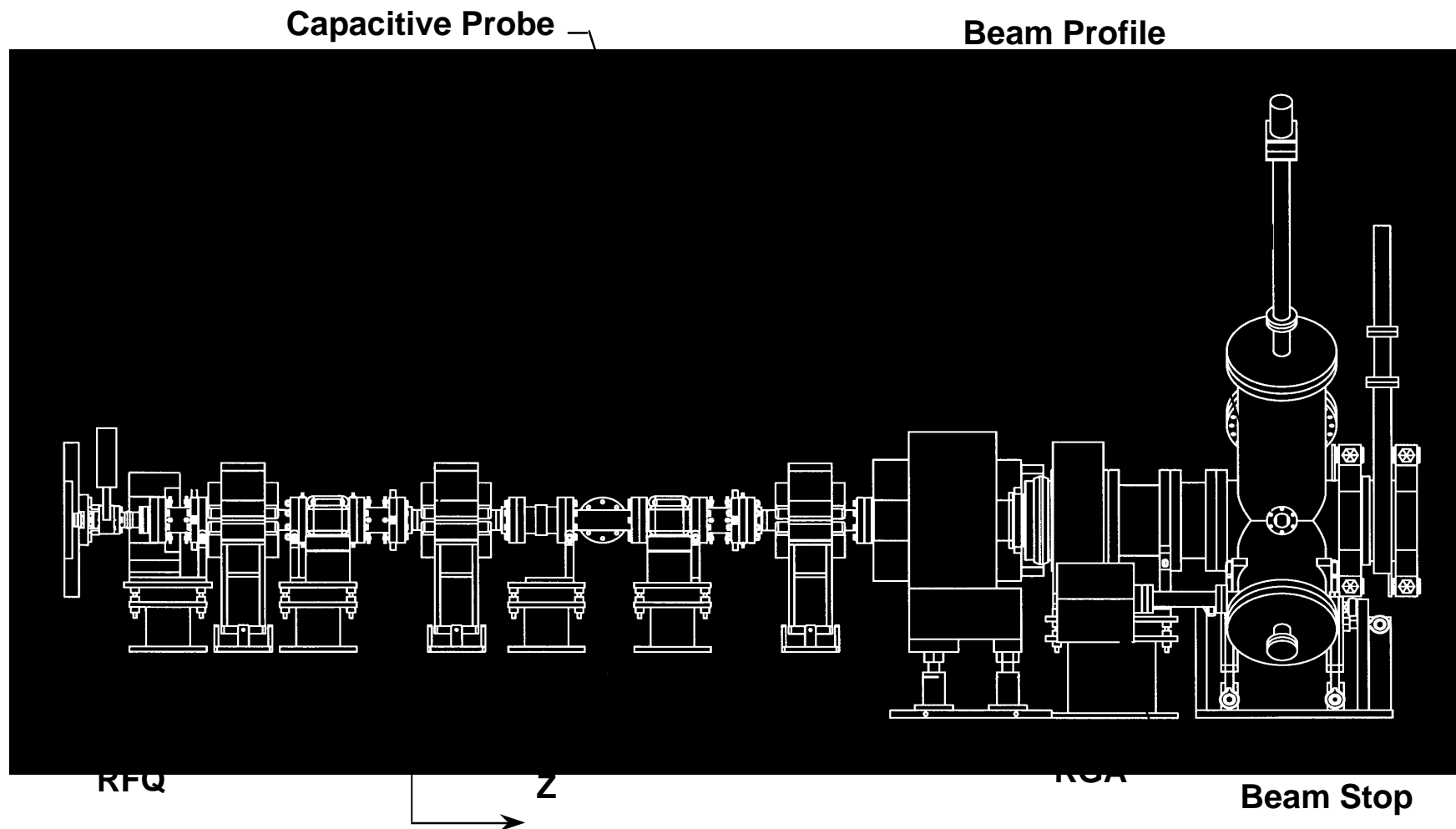
High-Power RF System equipment installed on the mezzanine

- Key HPRF system components
 - Klystrons, HVPS, circulators, switches, loads, and crowbars
 - Fault protection
 - RF waveguide
- Key HPRF system features
 - 350-MHz klystrons drive RFQ
 - 700-MHz klystrons drive CCDTL
 - Full-power collectors on klystrons
 - Testing advanced IGBT HVPS
- Key HPRF system parameters
 - Each of 6 rf windows operates at ≤ 360 kW, tested to ≥ 900 kW
 - Three 350-MHz systems deliver up to 2.4 MW to RFQ
 - One 700-MHz systems delivers up to 0.8 MW to CCDTL

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Layout of HEBT Beamline Optics and Diagnostics.

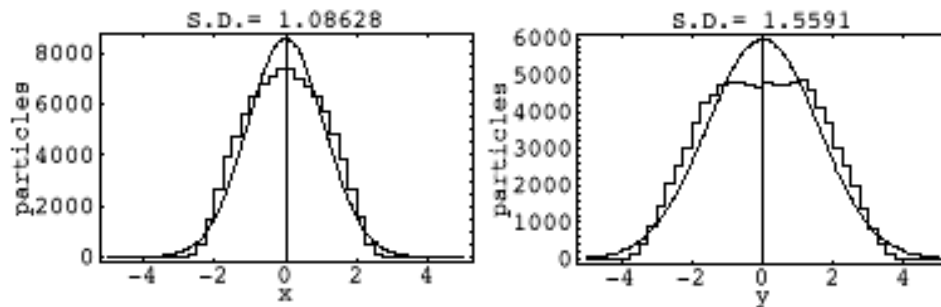


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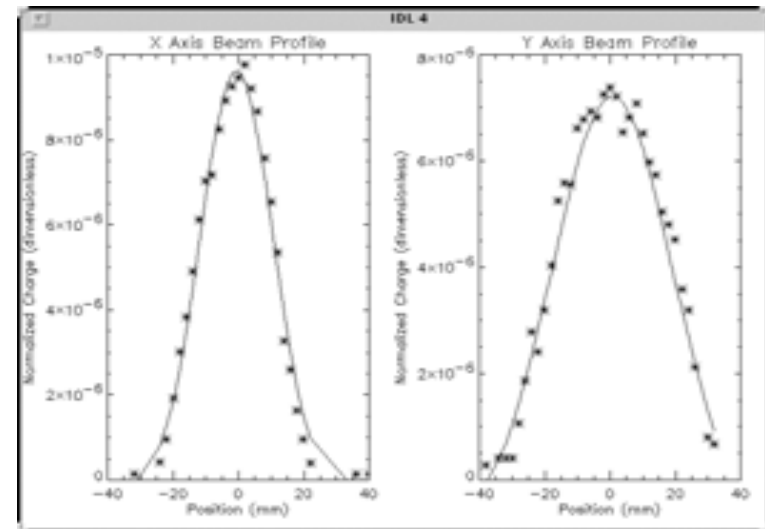
The HEBT is tuned to adjust the measured beam profiles to the design profiles.

Design Profiles



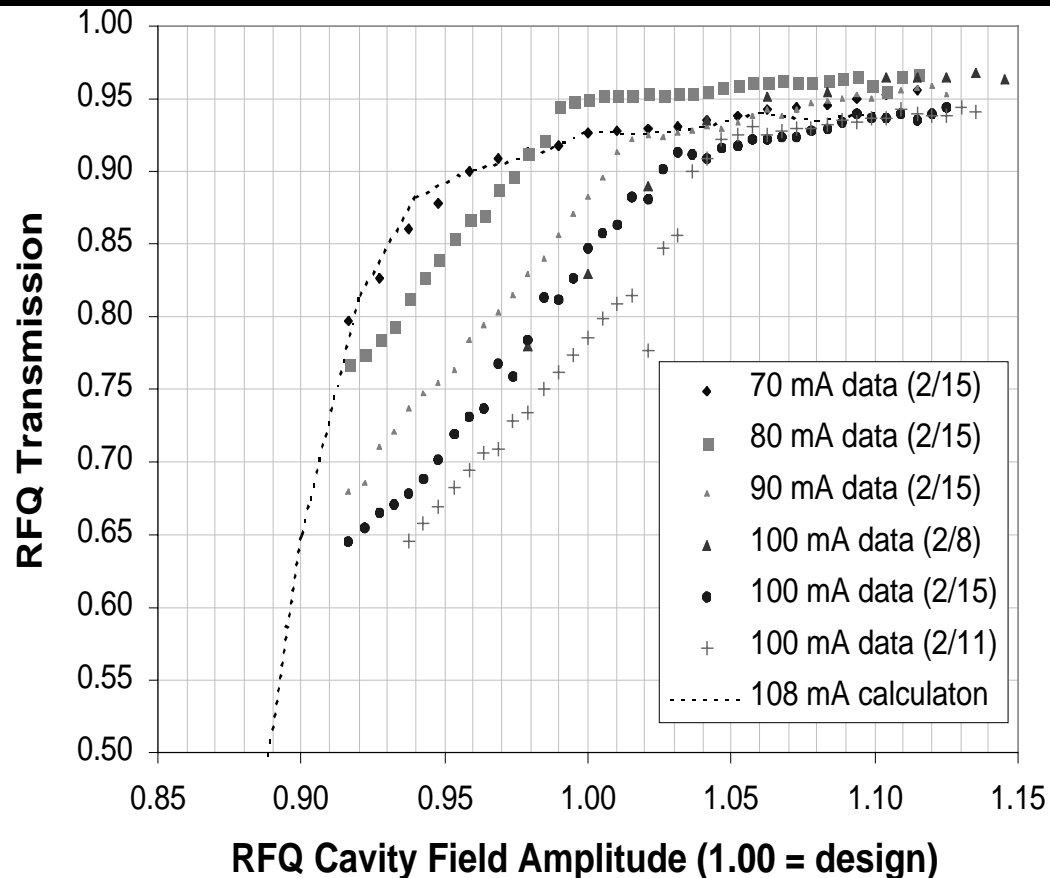
- The above LINAC (3D) profiles are at the wire scanner
- These profiles are for the nominal HEBT beam tune
- The x and y widths are 10.8 and 15.7 mm, respectively

Measured Profiles



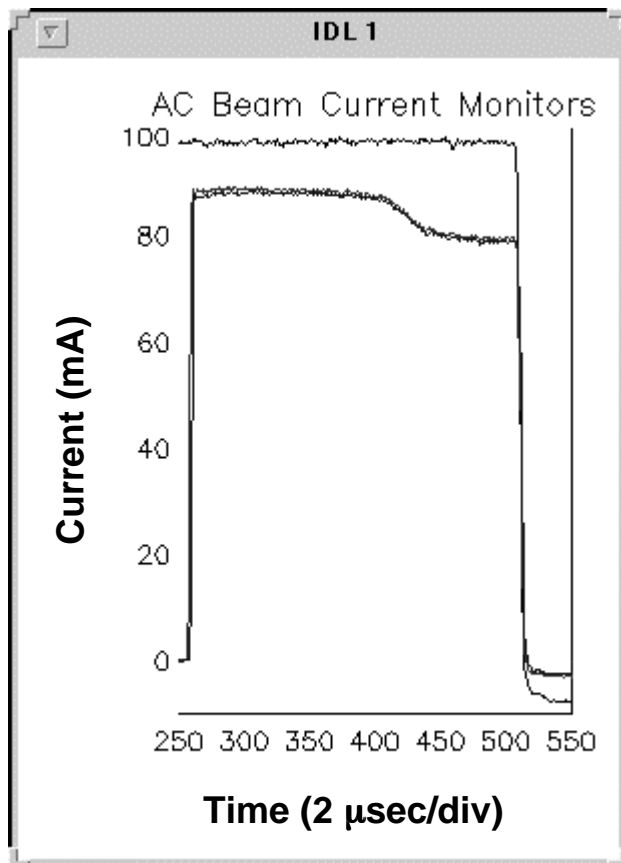
- The above measured profiles are for a 85-mA, 5-Hz, 100- μ sec pulsed beam
- The displayed widths are 9.1 and 13.9 mm in x and y, respectively

RFQ Transmission vs RFQ Cavity Field Amplitude for 1.5-msec Long Beam Pulses



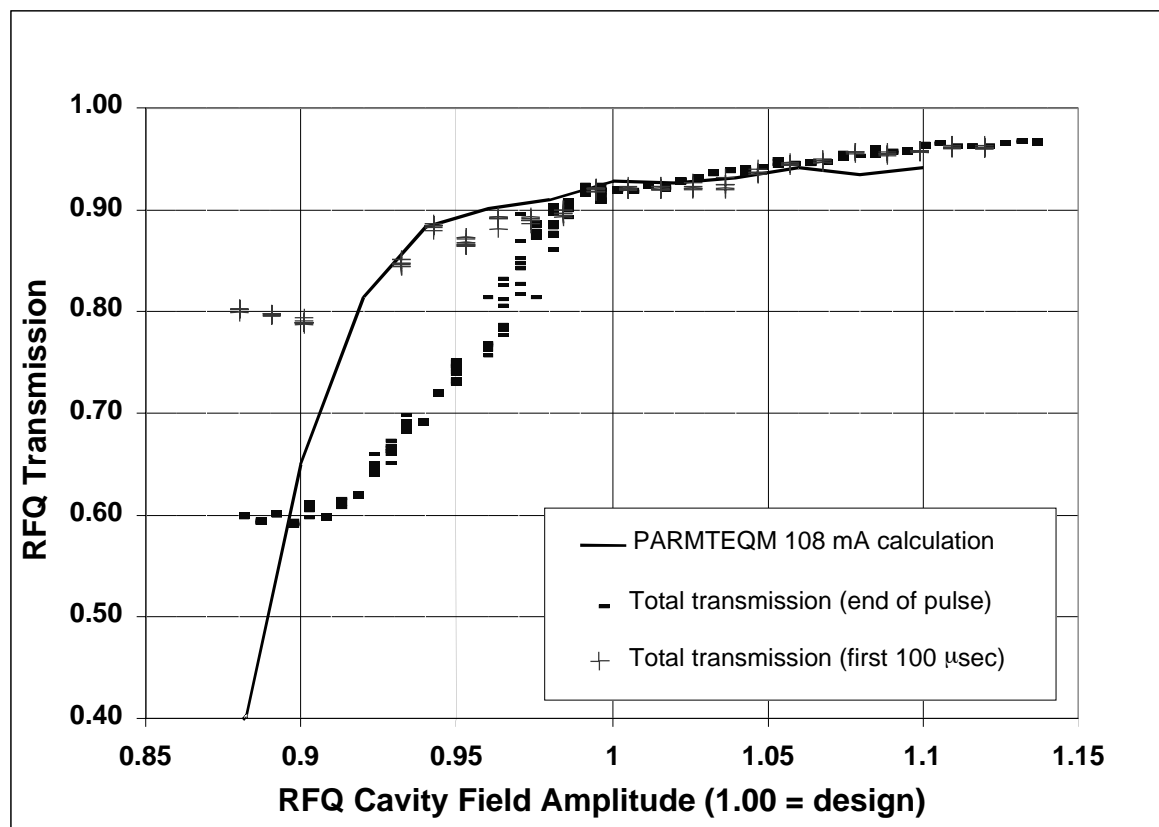
For currents ≥ 90 mA, raising the rf-field level to 1.05-1.10 of design increases the RFQ transmission to the PARMTEQM prediction.

The H⁺ beam current abruptly drops ≈ 300 μ sec into the pulse for currents >90 mA and RFQ field levels \leq design.



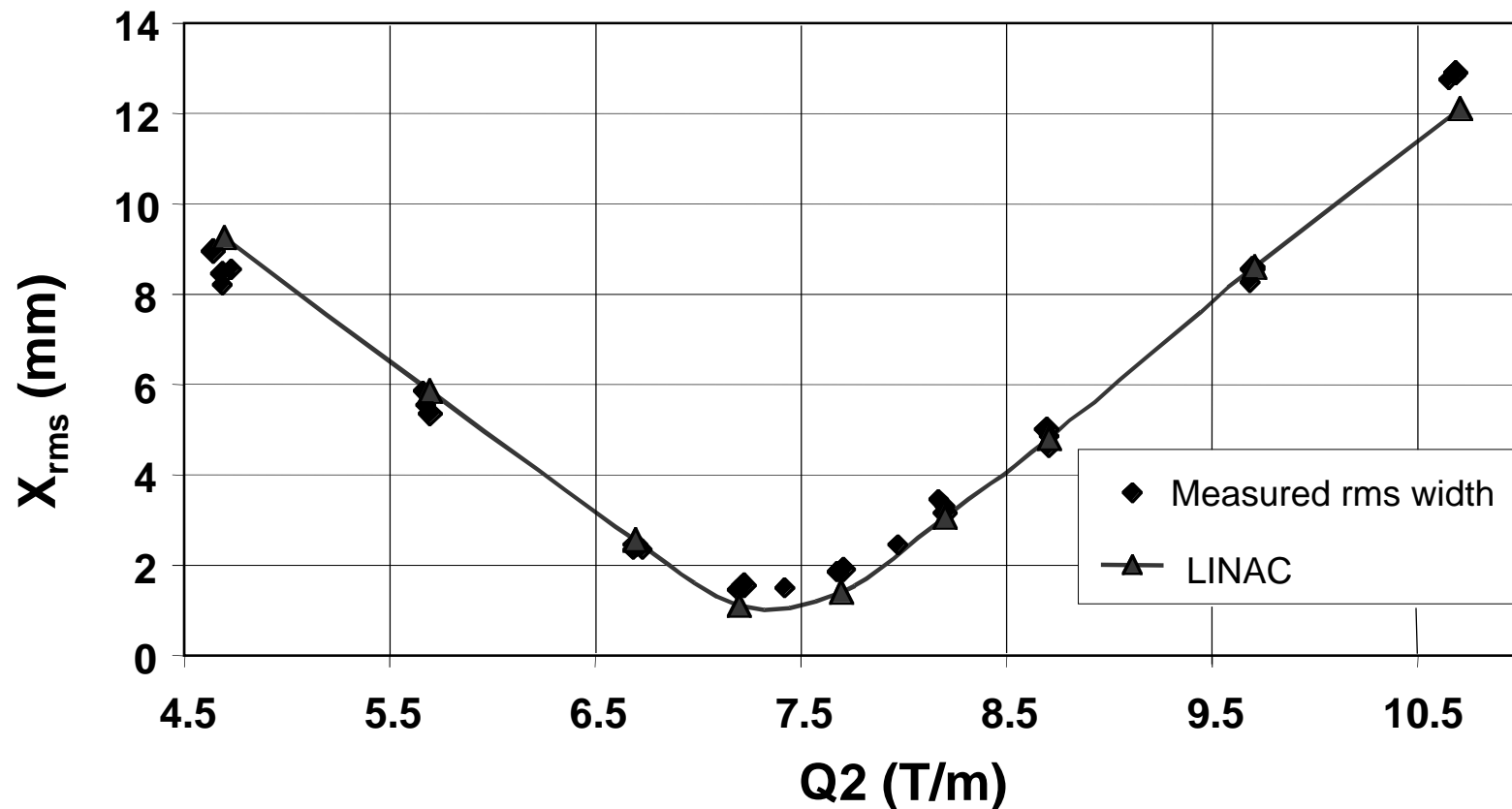
- For 105 mA injected into the RFQ (black)
- the RFQ output beam current (red) drops from 90 mA to 83 mA and the HEBT output current (blue) drops from 90 mA to 82 mA ≈ 300 msec into the 500 msec long beam pulse
- The rf field level is $\sim 90\%$ of the design field level for this measurement.
- Raising the rf field level to 1.05-1.10 of design eliminates this effect

RFQ Transmission vs RFQ Cavity Field Amplitude at the Start and End of 500- μ sec Long, 90-mA Beam Pulses



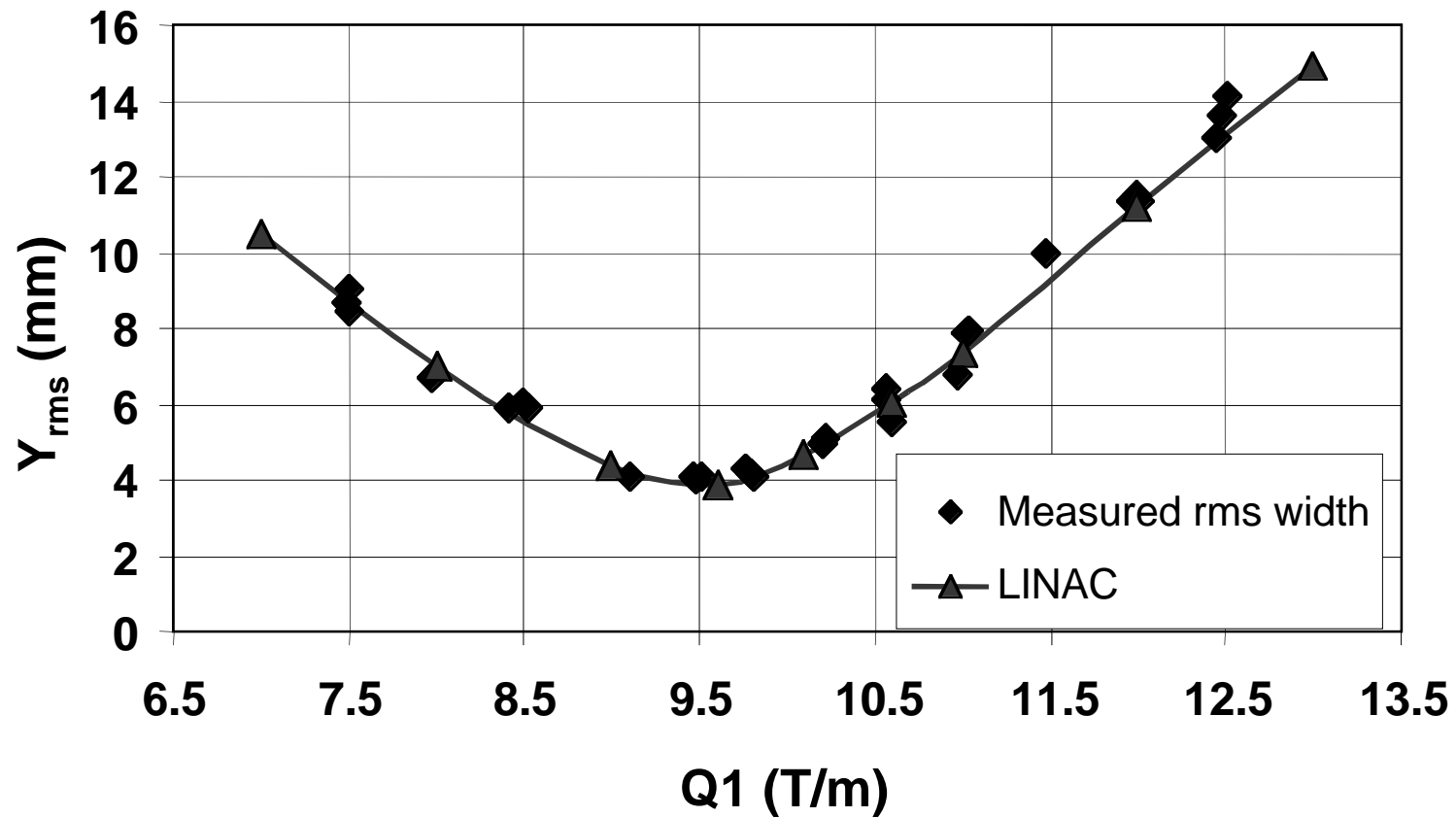
The total transmission at the start of the 90-mA pulse agrees with the PARMTEQM prediction for a 108-mA output beam.

X Quad Scans Analyzed with LINAC



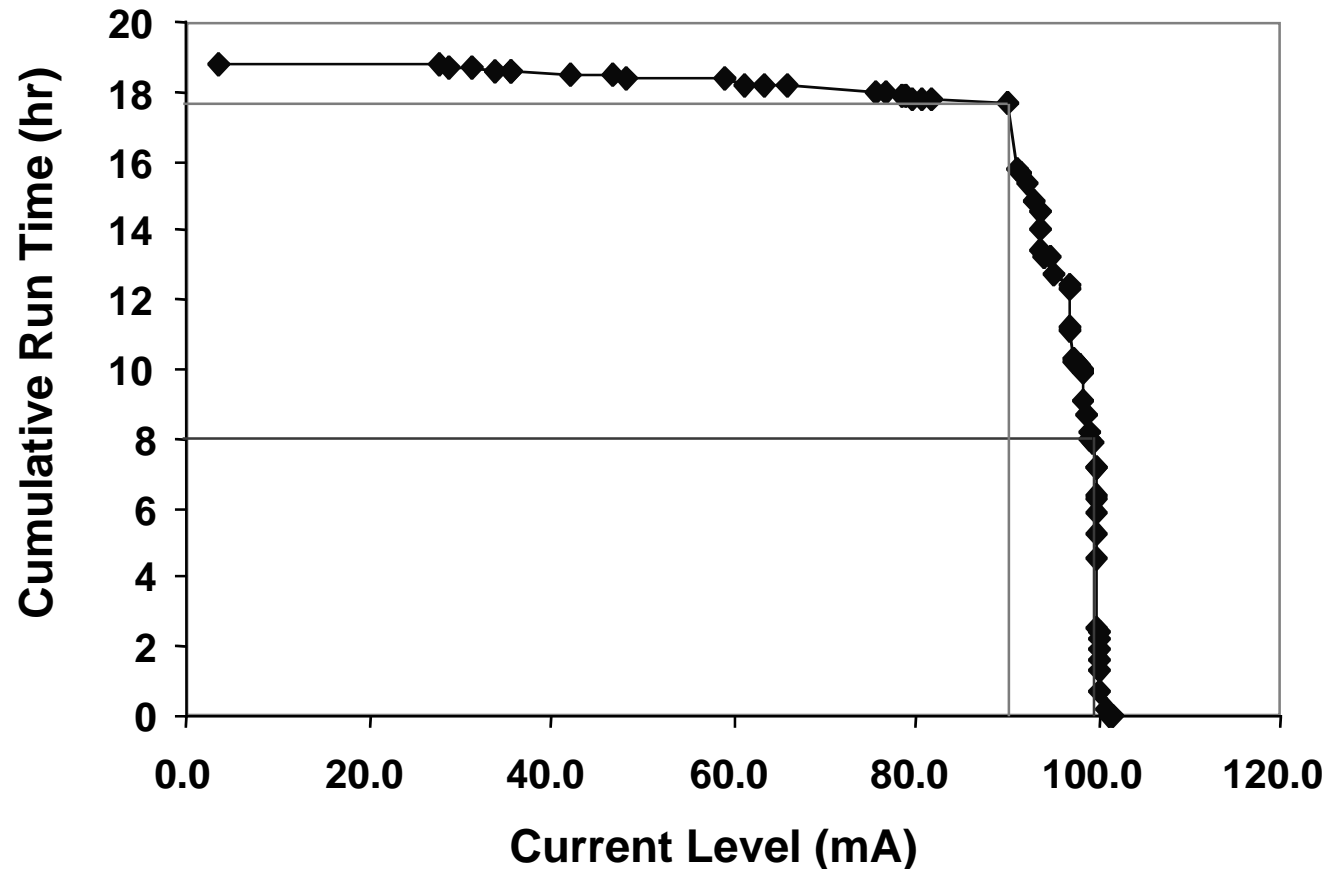
- The rms normalized emittance is $0.25 \pi \text{ mm mrad}$ in this LINAC model of the HEBT transport for the 93-mA beam
- The other Twiss parameters are $\alpha = 1.8$ and $\beta = 36 \text{ cm}$
- The estimated experimental error in ϵ_x is $+10\% / -50\%$

Y Quad Scans Analyzed with LINAC



- The rms normalized emittance is $0.31 \pi \text{ mm mrad}$ in this LINAC model of the HEBT transport for the 93-mA beam
- The other Twiss parameters are $\alpha = -2.5$ and $\beta = 90 \text{ cm}$
- The estimated experimental error in ϵ_y is +10% / -50%

The LEDA RFQ has >30 cumulative hr of operation with CW output currents ≥ 100 mA.



- The data shown above (8 hr >100 mA, 17 hr >90 mA) is for 12/17-12/22/99
- To date there are >30 cumulative hr of operation with CW output currents >100 mA and >70 cumulative hr of operation with CW output currents >90 mA

Summary

- 100 mA of RFQ CW output current has been achieved for an uninterrupted run of 116 min, with automatic fault recovery.
- High RFQ beam transmission, $\approx 94\%$, has been achieved.
- Overall RFQ accelerator system performance is better with the injector tetrode extraction system than with the triode.
- For output beam currents > 90 mA the RFQ transmission agrees with the PARMTEQM prediction provided the rf field level is increased to 1.05-1.10 of the design field.
- Preliminary analysis of the RFQ output beam emittance measurements indicates the rms normalized emittance $\varepsilon_x \approx 0.25 \pi$ mm mrad, within the experimental error of the PARMTEQM-predicted value of 0.23π mm mrad.